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REMOVAL AND DESTRUCTION OF PERCHLORATE AND OTHER ANIONS FROM GROUNDWATER USING ISEP+™ SYSTEM

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1.0 Introduction

Ion exchange is one of the most effective and economical techniques for the removal of ionic contaminants from groundwater. Ion exchange resins have been used for treating drinking water for several years[1]. Recently, there has been increased regulatory attention to the presence of perchlorate (ClO_4^-) in groundwater aquifers in California and several other states. Perchlorate in drinking water is believed to cause health problems for infants and patients with hypothyroidism by interfering with the ability of the thyroid gland to process iodine[2]. A provisional action level (PAL) of 18 ppb perchlorate has been established in California. Calgon Carbon has been successful in piloting a total treatment technology for the removal and destruction of perchlorate and other contaminant ions (nitrate and sulfate) from groundwater. The technology (ISEP+™) incorporates a continuous countercurrent ion exchange system (ISEP®) for the removal of perchlorate, nitrate and sulfate from the water. The spent brine, after regenerating the resin in the ISEP system, is treated by the perchlorate and nitrate destruction module (PNDM) that reduces the perchlorate and nitrate to chloride and nitrogen, respectively, and also features a nanofiltration unit to remove the sulfate present in the brine. The 'purified' brine is recycled back into the ISEP system as regeneration feed. The entire process results in a very small waste stream free of perchlorate and nitrate that can be easily disposed. A schematic of the ISEP+ treatment system is shown in Figure 1.

2.0 Experimental/Pilot Methodology

Pilot-scale testing was conducted with a proprietary resin at two different field sites (San Gabriel's Big Dalton site and Jet Propulsion Laboratory site) for a total period exceeding six months. Testing was conduced with the pilot-scale ISEP unit designed to treat feed water at 4.28 GPM. Regeneration was conducted using a 7% NaCl solution. The pilot testing covered various objectives ranging from waste minimization to performance validation at varying influent perchlorate concentrations. Over the course of the two pilot studies, the ISEP system successfully treated over 750,000 gallons of contaminated groundwater. The brine effluent from the ISEP system was treated by the catalytic reactor followed by a nanofiltration (NF) system for removal of sulfate. A slight stoichiometric excess of ethanol, which gets oxidized to carbon dioxide and water during the reaction, was used as a reductant in the catalytic reactor. The samples generated were analyzed by ion chromatography (EPA method 300.0 *modified*) for perchlorate and other anions. The perchlorate analytical detection limit is reported to be 4 ppb for water samples and 125 ppb for most brine samples.

3.0 Results and Discussion

The steady state performance results obtained for removal of perchlorate by the ISEP system from a perchlorate-contaminated groundwater stream are shown in Figure 2. The system continuously produced treated water with non-detectable levels of perchlorate. This performance

was maintained during the regeneration optimization and when the waste (brine effluent) from the system was reduced to 0.5% (vol.% of feed water), perchlorate breakthrough was observed, although a level below the California PAL was still maintained. The feed perchlorate concentration was spiked to 60-80 ppb during the test as the well head concentration declined. At the optimal waste level of 0.75%, the system produced non-detectable perchlorate in treated water. This level of waste corresponds to a salt consumption of 9.8 lbs/ft^3 of resin. The ISEP system concurrently reduced the influent nitrate concentrations from ~22-28 ppm down to 5-14 ppm during the same period of operation, as shown in Figure 3. Moreover, influent sulfate concentrations of 45-60 ppm were also concurrently removed to <2 ppm in treated water. It was shown during the pilot test that at an operating waste level of 0.75%, effective removal of perchlorate, nitrate and sulfate can be achieved by the ISEP system.

The second pilot test at JPL expanded on the results obtained from the Big Dalton pilot study to explore the performance of the ISEP system at high perchlorate concentrations. Results showed that for a modest increase in regenerant consumption, the system was able to produce non-detectable level of perchlorate in treated water with similar nitrate and sulfate removal results as the earlier study, even at influent perchlorate concentrations around 1200 ppb. Table 1 summarizes the perchlorate removal results and the optimized regenerant waste level generated at the different feed conditions during the pilot studies. Detailed performance analyses of the two pilot studies will be presented during the presentation.

Table 1. Summary of steady state ISEP® performance at different perchlorate feed conc.

Influent perchlorate concentration (ppb)	Treated water perchlorate concentration (ppb)	ISEP Regeneration effluent (brine), as vol.% of feed water treated
50-80	< 4	0.75%
~250	< 4	~1.25%
~1200	< 4	1.75%

In addition to ISEP, the PNDM tested at the second pilot site showed that the catalytic reactor system was effective in achieving near-complete destruction of perchlorate as in the brine effluent from ISEP, as shown in Figure 4. Moreover, near-complete destruction of nitrate was also achieved in the reactor system. The NF system was able to recover 91% of the brine from the catalytic reactor at a 96% sulfate rejection rate, thus producing a 9% purge stream, which is now the only process waste stream. This indicates that the integrated ISEP+™ system is successful in reducing the already low ISEP waste stream by an order of magnitude. In other words, for a 1200 ppb ClO_4 feed, at the ISEP regeneration effluent level of 1.75%, the total process waste is around 0.175% of the feed water treated. The 'purified' brine stream can also be recycled, which greatly reduces the regenerant salt requirements and operating costs. In addition, the low waste stream generated is free of perchlorate and nitrate and can be easily disposed.

4.0 Conclusions

The results obtained from Calgon Carbon's laboratory and pilot studies indicate that perchlorate and other anions in groundwater can be effectively and efficiently removed by the ISEP system to produce a high quality treated water that far exceeds the specifications. The superior performance is maintained while consuming low amounts of regenerant. In addition, the PNDM can achieve near-complete elimination of perchlorate and nitrate and substantial removal of sulfate from the ISEP brine effluent. The 'purified' brine stream can be recycled as regeneration feed back into the ISEP system. The entire process (ISEP+) produces a small waste stream for disposal that contains no perchlorate and nitrate.

5.0 References

1. Sengupta, A.K., ed., *Ion Exchange Technology: Advances in Pollution Control*, Technomic Publishing, Lancaster, 1995.
2. 'Final Report of the Perchlorate Research Issue Group Workshop', *AWWARF*, Sept.30-Oct.2, 1997, Ontario, CA.

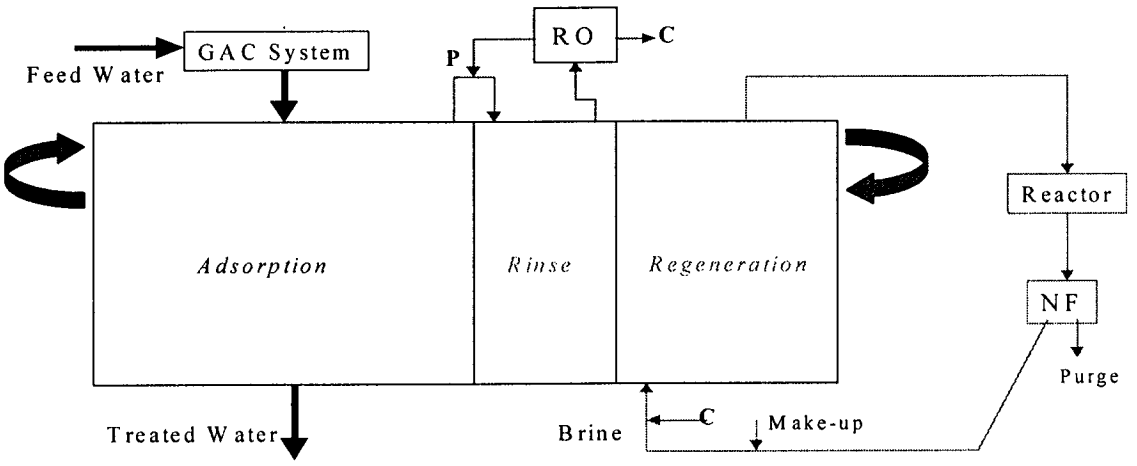

Figure 1. Schematic of the ISEP+™ perchlorate removal and destruction process.

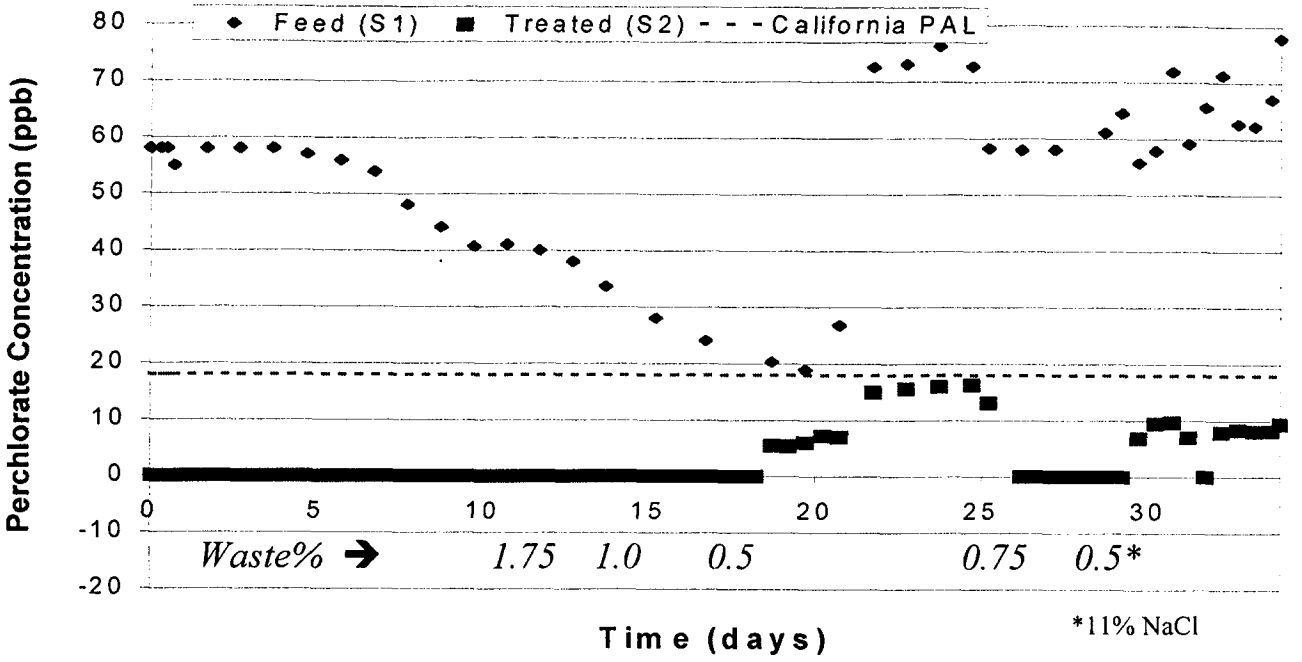

Figure 2. Removal of perchlorate from groundwater using ISEP® system.

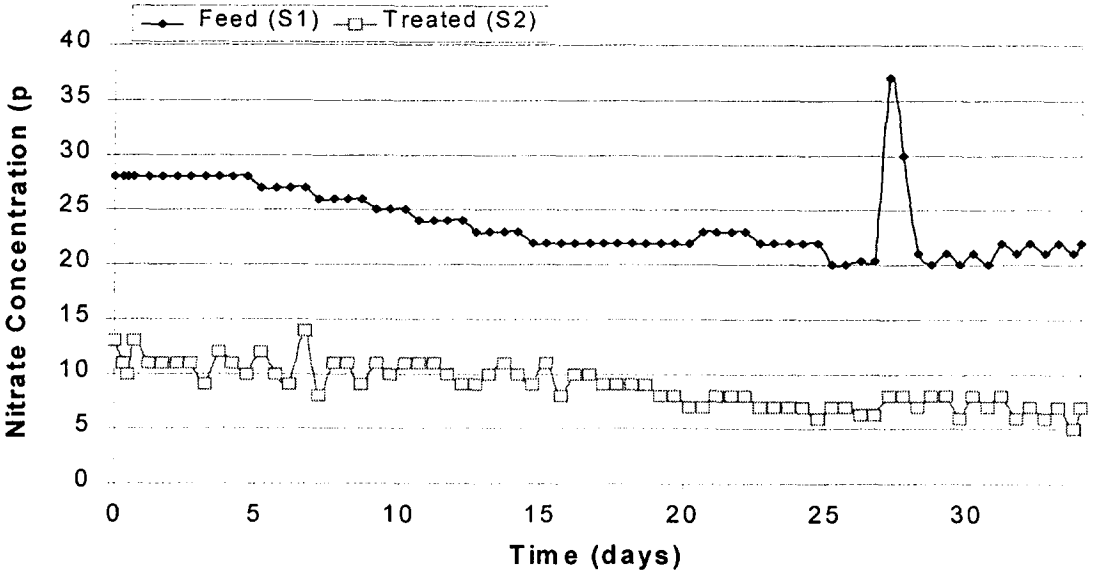

Figure 3. Removal of nitrate from groundwater using ISEP® system.

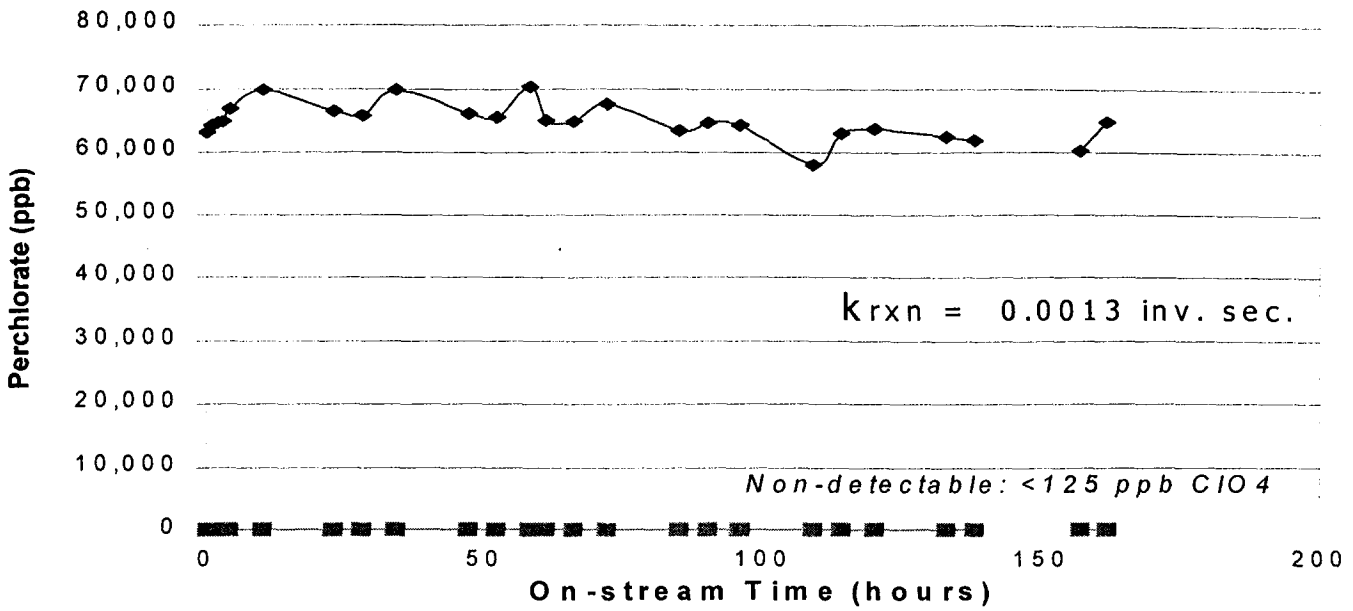

Figure 4. Destruction of perchlorate in ISEP® brine effluent by the catalytic reactor system in PNDM.